Rebuttal Report of Randolph C. Fischer, P.E.

Introduction

This report summarizes the opinions of Randolph C. Fischer, P.E., regarding the written testimony given by Gene Andrews in this matter. Mr. Fischer is providing his expert opinions at the request of Mr. Luke Cole, Director of the Center on Race, Poverty & the Environment, 450 Geary Street, Suite 500, San Francisco, CA 94102.

Mr. Fischer reserves the right to modify and supplement his opinions as further information becomes available, including through deposition of defendant's experts, and to express new opinions in response to new information or to opinions expressed by defendant's experts. Additionally, Mr. Fischer has not been given access to several of the reports and publications on which Mr. Andrews relied in making his expert opinion; Mr. Fischer has been informed by plaintiffs' counsel that these documents were requested of Teck Cominco but have not been provided to the plaintiffs. Mr. Fischer reserves the right to modify and supplement his opinions once he has been provided all data and publications on which defendant's experts relied. In reviewing the Expert Report of Gene Andrews, a number of lines of text were printed on top of each other, making it difficult and sometimes impossible to read the lines. This includes, but is not limited to, lines on page 2 (paragraph 2), page 3 (paragraphs 3 and 4), page 4 (paragraph 13, 15, 16), page 9 (paragraphs V and VI), and page 12. Mr. Fischer reserves the right to modify and supplement his opinions once these lines of text are provided in a legible form. The fact that Mr. Fischer has focused only on certain statements in Mr. Andrews' report does not reflect his acceptance or agreement with those statements not specifically addressed herein.

Materials Reviewed

In addition to relying on his experience as a professional environmental engineer, Mr. Fischer bases his opinions in this matter, in part, on reviewing the following reports and publications:

1. Andrews, G., T. Mudder, M. Botz, and D. Howe. 1996. *Effluent Treatment and Water Management for TDS Control – Red Dog Mine*. December 1996 for Cominco Alaska, Inc.

2. Andrews, G., T. Mudder, M. Botz, and D. Howe. 1997. *Effluent Treatment and Water Management for TDS Control – Red Dog Mine*. September 1997 for Cominco Alaska, Inc.

3. Andrews, G., T. Mudder, M. Botz, and D. Howe. 1999. *Effluent Treatment and Water Management for TDS Control – Red Dog Mine – 1999 Update*. March 1999 for Cominco Alaska, Inc.

4. Andrews, G. 2004. *Expert Report of Gene Andrews*. Case No. A04-00049 CV. November 15, 2004.

5. Kempton, H., M. Martin, and T. Martin. 2003. *Comparative Cost Analysis of Technologies for Treating Sulfate- and Metal-Contaminated Groundwater*. Acid Rock Drainage Sixth International Conference, 12-18 July, Cairns, North Queensland, Australia.

6. FWR. 2000. *An Economic and Technical Evaluation of Regional Treatment Options for Point Source Gold Mine Effluents Entering the Vaal Barrage Catchment – Final Report.* Report No. 800/1/00.

7. Teck Cominco Alaska. 2002. *Discharge Monitoring Report for Red Dog Mine.*

Opinions and Observations

This section presents Mr. Fischer's general observations and opinions regarding the November 15, 2004, expert report submitted by Mr. Gene Andrews.

At least as early as 1996, the treated effluent discharged from the Red Dog mine caused exceedances of the in-stream limits for total dissolved solids (TDS) in the receiving stream, Red Dog Creek. As early as 1996, Cominco Alaska, Inc. (Cominco), the mine's operator, was aware of the TDS exceedances of the in-stream standards and was petitioning the Alaska Department of Environmental Conservation (ADEC) to reclassify the streams receiving mining effluent. In addition Cominco was petitioning ADEC to develop site-specific stream standards or criteria for mine effluents in receiving streams. In the interim, however, ADEC or the State of Alaska requested that Cominco provide an update and review of potentially applicable technologies for treating or managing the waters being discharged from the site. In 1996, 1997, and 1999, Mr. Andrews prepared and submitted a series of reports on behalf of Cominco to meet ADEC's request for a feasibility analysis of applicable technologies. Mr. Andrews' expert testimony relies primarily on the 1997 report to conclude that reducing the levels of TDS discharged from the mine to levels capable of meeting the stream standards was infeasible.

Overall Opinions

Based on his experience in mine water treatment and management and in preparing engineering feasibility studies, Mr. Fischer believes the screening of TDS removal technologies and options performed by Mr. Andrews between 1996 and 1999 on behalf of Cominco was incomplete and inadequate in judging the true feasibility of TDS reduction alternatives at the mine. Instead, the work performed by Cominco appears designed merely to delay possible enforcement of the existing stream standards until site-specific standards might be adopted rather than to actually remedy the TDS exceedances caused by the company's discharges. This opinion is based on the following:

- Cominco's efforts to address the TDS exceedances in Red Dog Creek appear limited to performing screening-level evaluations on a small number of potentially applicable technologies. These rather cursory evaluations are presented as evidence of the infeasibility of TDS reductions in the mine's effluent;

- Over a 4-year period from 1996 through 1999, no less than 3 versions of the same technology screening report were prepared to evaluate TDS reduction strategies at Red Dog Mine. These technology evaluations were, at best, suitable as the initial steps in a more thorough and defensible feasibility study. However, over the 4-year period in which these

reports were prepared, the level of detailed analysis remains cursory, with no evidence of any bench testing, conceptual designs, or more detailed cost estimates being performed;

- In contrast to the technology screening reports submitted by Cominco, an adequate and complete engineering feasibility study should have included elements, such as the following:

  - development and screening of a set of comprehensive alternatives for reducing TDS based on the initial technology screening steps;
  - detailed analysis of a set of potentially viable candidate alternatives;
  - possible bench-or pilot-scale treatability studies;
  - conceptual-level engineering designs and calculations;
  - cost analyses with a higher level of certainty than are used in the initial screening step.

- The documents supporting Mr. Andrews' conclusions tend to evaluate the technical capabilities of TDS reduction strategies in isolation from other potentially applicable technologies, i.e. no comprehensive approaches to TDS reduction were presented or evaluated. However, feasible solutions for reducing TDS concentrations in the mine's effluent would most likely exist in the form of comprehensive alternatives consisting of combinations of technologies, such as runoff collection/control and segregation of the most polluted water sources coupled with some form of treatment and on-site disposal of treatment residuals.

- In the absence of a complete and adequate engineering feasibility study, it is not possible to conclude that significant reductions in TDS were infeasible, as Mr. Andrews so concludes based on the technology screening reports submitted on behalf of Cominco in 1996, 1997, and 1999;

- Additionally, the TDS technology screening reports submitted on behalf of Comino are characterized by presumptions of infeasibility. That is, the technical infeasibilty of TDS reduction appears to be presupposed throughout, as evidenced by the following:

  - repeatedly questioning the justification for the applicable regulatory standards;
  - the lack of detailed engineering and chemical information;
  - evaluations based on exaggerated, qualitative, and speculative assertions rather than objective analysis;
  - a lack of detailed cost analysis and cost data back-up;
  - repeated speculation that there would be no environmental benefit from reducing TDS concentrations, yet providing no chemical or water quality data adequate for documenting the toxicity of the particular TDS being discharged;
  - exaggerated cost and time-frame estimates for implementing technological remedies;
  - a general absence of supporting documentation, such as water quality data, accurate flow volumes, or removal efficiencies.

Specific Observations

The following specific observations of Mr. Andrews' expert report are provided in support of Mr. Fischer's opinions stated in this report:

Water Balance, Water Quality, and Treatment Volumes

Frequently, the most cost-effective water quality improvements at mine sites involve the concept of keeping clean water, such as precipitation and run-on, clean through appropriate water management strategies while treating only the smallest possible volumes of dirty water, such as ore processing waters and mine drainage. Treatment options may become more feasible if the volume of water requiring treatment can be significantly reduced. However, opportunities for cost-effective water management and flow reduction measures were not seriously considered and could not be adequately evaluated given the confusing, inadequate or missing data presented in Andrews' reports (Andrews 1996, 1997, and 1999), as follows:

- Andrews (2004) characterizes TDS control as infeasible based, in large part, on the huge volumes (10,000 gpm) of effluent requiring treatment. Instead, supporting documents frequently suggest that a wide range of treatment options might be feasible if the flow rates were smaller. Yet, opportunities to reduce the volume of mine water requiring treatment are given only cursory consideration in the technology screening reports with no supporting water quality or flow data to back up the qualitative evaluations (Andrews, 1997, p. 31).

- The technology screening reports fail to provide a clear understanding of the site's hydrology and water balance for the purposes of evaluating runoff collection and control, split treatment, or separate treatment alternatives. For example, Andrews (1997) indicates in Table 6 (p.32) that site runoff comprises 80 percent (8,000 gpm) of the inflows to the treatment plant, whereas Figure 4 (p. 10) of the same report indicates site runoff accounts for only about half of the inflows. If, indeed, 50 to 80 percent of the treated effluent was comprised of runoff, why were no runoff control measures evaluated other than those currently in place at the mine site?

- Andrews (1996, 1997, and 1999) consistently states that the technology screenings he performed were based on an assumed flow rate of 10,000 gallons per minute (gpm). To support this assumption, Andrews (1996, p. 19 and 1997, p. 21) indicates "the total treatment system throughput was 15,000 gpm, with 10,000 gpm being intermittently discharged from the site and 5,000 gpm returned to the mill in an internal recycle loop." However, Andrews (1999, p.18) later states that the total treatment system throughput in 1998 ranged from 3,200 gpm to 7,900 gpm with an annual average flow rate of 4,820 gpm. This is approximately half the discharge estimated for 1996 and 1997. There is no explanation of how this significant reduction in flow rates was achieved nor any reexamination of the design assumptions for the technology screening. Still, the flow data presented in 1999 appear to indicate there were opportunities to reduce the flow rates from the stated design assumption (10,000 gpm), thereby altering the presumption of infeasibility for some of the evaluated treatment options.

- Cominco's discharge monitoring report (DMR) for 2002 indicates the volume of water being discharged from the treatment plant was reduced by roughly half the amount being discharged in 1997. This reduction in flow is further evidence that cost-effective water management or flow reduction strategies should have been considered in the evaluation of treatment technologies in Andrews' technology screening reports, as well as his expert report (Andrews 2004).

- An adequate TDS mass balance for the site is not presented in the company's reports, thereby obscuring possible opportunities for managing or treating various water sources differently. For example, **based on no water quality data**, Table 6 (Andrews, 1997, p. 32) indicates up to 67 percent of the TDS load for the site is attributable to site runoff. Yet, no TDS load is attributed to the ore processing or water treatment chemicals that are likely the largest TDS components. Feasible solutions for reducing site-wide TDS loads may have been overlooked because of the poor understanding the TDS mass balance represented by Table 6.

- A complete ion balance, as well as an accurate mass balance are the primary prerequisites for identifying and screening potentially applicable TDS treatment technologies. However, no ion balance is ever presented in any of the technology screening documents. Table 2 (Andrews 1997, p. 15) presents a broad analysis of the site-specific TDS indicating the water is primarily a calcium/magnesium sulfate type effluent. The absence of more detailed water quality information, such as an ion balance renders a true assessment of TDS treatment technologies difficult. For example, gypsum (calcium sulfate) solubility limits obtained through geochemical modeling would be an important parameter for evaluating the potential effectiveness of chemical treatment methods. Andrews (1997, p. 33) indicates the mine effluent is near the saturation point with respect to gypsum. However, there is no follow up discussion on the feasibility of reducing sulfate concentrations through gypsum precipitation technologies.

- Andrews (1997, pp. 15-16) characterizes the TDS at the Red Dog mine as non-toxic except at very high concentrations. This characterization, as well as a lengthy discussion of the regulatory framework (Andrews 1997, p. 5-8) lead to Andrews' (2004, p.7) statement that the environmental benefits of TDS treatment at the Red Dog Mine are not quantifiable. Such characterizations weigh heavily in Andrews feasibility evaluations. Yet, conclusions regarding the non-toxic nature of the TDS at Red Dog Mine are not backed up with any water quality data, whole effluent toxicity (WET) testing results, or ecological risk assessments. The TDS in mining effluent frequently contains potentially toxic metals, metalloids and anions in their dissolved forms. Hence, mine-site TDS cannot be merely assumed non-toxic in the absence of a complete ion balance or WET test results. There are references to ongoing bioassays in the receiving streams (Andrews 1997, p. 8). But no data are presented to support the assumption of non-toxicity.

Technology-Specific Evaluations

Often, Andrews' speculates about the treatment efficiencies or performance of specific technologies under site-specific conditions concluding these technologies are infeasible to implement. Seldom are any back-up data provided to support these speculative comments. Specific technologies are only evaluated in isolation, never considered in combinations or for use in split-flow treatment systems, i.e. for treating only part of the flow or treating different flows using different technologies to optimize TDS reductions.

- Andrews (2004, p. 5) states that, "Interim treatment options were all unproven for the TDS levels and flows involved with the Red Dog effluent." This statement is false. Several of the treatment technologies evaluated in Andrews' technology screening reports were well proven in 1997 for removing TDS from waters many times more brackish than the Red Dog effluent. In addition, some commonly used treatment technologies are available for achieving the relatively low to moderate removal efficiencies needed for compliance.

- Andrews (1997, p.23) states as an assumption for his technology evaluations that the mine discharge would need to achieve a TDS concentration between 200 mg/L to 1000 mg/L from an average concentration of 2500 mg/L to meet the in-stream standards. This would require removal efficiencies ranging from 60 percent to 92 percent. Later, in 1999, Andrews (1999, p. 20) states that TDS concentrations would need to be reduced from between 2600 mg/L to 3120 mg/L down to 1000 mg/L and 1900 mg/L to meet the in-stream limits. This only would require removal efficiencies ranging from 27 percent to 67 percent.

- The technical feasibility problems cited for membrane technologies are overstated. Andrews assumes all 10,000 gpm would be treated, whereas it might be most cost-effective to treat only a portion of the flow. For example, because divalent anions, such as nitrate and sulfate are probably the most recalcitrant TDS constituents, it might be highly feasible to segregate the major nitrate and sulfate loading sources (i.e. mine drainage) and treat those sources by nano-filtration to remove nitrate and sulfate before combining with other wastewater sources. Once the sulfate loads are reduced, it could be possible to remove other TDS constituents using conventional chemical treatment, possibly in the existing treatment plants. Unfortunately, data presented in the technology screening documents are insufficient to evaluate such possible alternatives, nor were any such split-flow alternatives developed or evaluated by Andrews.

- Andrews assumes that deep-well injection would be the only possible alternative for disposing of the concentrated reject stream from an RO or nano-filtration system. However, chemical treatment would also be possible and would likely be readily feasible.

Exaggerated Cost Estimates

In Mr. Fischer's opinion, the cost estimates presented in the technology screening documents (Andrews 1996, 1997, and 1999) are exaggerated, as follows:

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- The stated level of accuracy for the cost estimates (+/- 40 to 50 percent) is too broad for meaningful evaluation of the options. In addition, it is unclear if the cost figures presented in Table 8 (Andrews 1997, p. 39) represent the median costs or the upper or lower bound costs of the stated range of accuracy. Assuming the costs presented in Table 8 represent the median of the range of accuracy, then the capital construction costs for RO, for example, could range between $41.25 million to $68.75 million.

- Although the area multiplier of 2.5 seems excessive, it is granted that any construction in such a remote location would be considerably more expensive than in the mainland US.

- The level of contingency allowances for the capital costs is quite large, ranging from 18 percent for the ocean pipeline option to 40 percent for deep-well injection and reverse osmosis.. These large contingency factors appear to be in addition to the already wide range of accuracy. These large contingency factors have the effect of inflating the cost estimates and enhancing the impression that the technologies are prohibitively expensive.

- No cost sensitivity analysis is presented in Andrews' reports (1996, 1997, and 1999). For example, the cost detail presented for RO treatment failed to examine the affects of scaling down the size of the system from 10,000 gpm. Also, only the most expense method for brine disposal was included in the costs, i.e. evaporative disposal, while other disposal or treatment methods might be less costly. Hence, it appears only the upper bound costs estimates are presented in Table 8 and Appendix A (Andrews 1997), whereas sensitivity analysis might reveal alternatives that cost significantly less.

- Instead of normalizing the costs to present-day dollars by performing a present worth analysis, the capital and operating and maintenance (O&M) costs presented in Table 8 (Andrews 1997) are simply summed over the assumed 15 year life cycle, plus interest on the capital costs. This makes the cost appear much higher than necessary, whereas present worth analysis would give a more realistic representation of the costs in terms of present-day dollars. For example, Andrews (1997, Table 8, p. 39) indicates the 15 year owning cost of the RO treatment system would be $153.5 million. In contrast, present worth analysis for the same RO system reveals that the present worth of the RO option (total capital and O&M costs over 15 years) would range between $81.8 million and $88.8 million assuming a discount rate of 5 percent and 3 percent, respectively.

- Present worth can be interpreted as the total investment required today to build and operate a plant over its estimated life cycle. Present worth costs are often preferred for comparative analysis of alternatives because they normalize the costs of all alternatives to present day dollars.

- The interest rate or discount rate applied by Andrews (1997, Table 8, p. 39) to his cost analysis is 2 to 3 times higher than interest rates in recent history. The use of a 10 percent interest rate has the effect of greatly inflating the cost estimates. Inflation over the past decade has only ranged between 1 to 2 percent per year.

Possible Alternatives Not Considered

Andrews (2004, and 1996 – 1999) failed to consider many currently available, proven or experimental technologies for reducing TDS concentrations in mining effluent. Some these technologies were available in the mid-1990s when Andrews work on behalf of Cominco was performed, although the timeframe of availability for others in unknown to Mr. Fischer. Possible treatment options not considered include the following:

- Gypsum precipitation using lime (reduces sulfate to <1,000 mg/L), known and available for decades;
- Barium Salts – precipitates sulfate in the form of barium sulfate, known and available for decades;
- SAVMIN – gypsum precipitation using lime and bauxite refining residuals called ettringite (reduces sulfate to < 200 mg/L), documented uses by late 1990s;
- Cost-Effective Sulfate Removal (CESR) – Similar to the SAVMIN process;
- GYP-CIX –sulfate removal using fluidized bed ion-exchange resins and generating a gypsum sludge that could be disposed of on site (reduces sulfate to < 200 mg/L), reported in *Environment and Water Management* in 1992;
- SPARRO – modified RO system, precipitates gypsum on seed crystals instead of on membrane surfaces, thereby reducing membrane fouling (reduces sulfate to < 200 mg/L);
- Nano-filtration with lime treatment of the brine stream, patented by HW Process Technologies (reduces sulfate to < 200 mg/L);
- Hydrothermal Sulfate Reduction (HSR) – Developed by the Wren Group Pty. Relies on the sensitivity of gypsum solubility limits to temperature to precipitate sulfate in the form of gypsum;
- Biosulfate – biologically reduces sulfate to sulfide and precipitates a wide range of metals for possible economic recovery, pilot plant operating at Britannia Mine, B.C., Canada, prior to 1997;
- Biological sulfate reduction combined with zero-valent iron (ZVI) – ZVI acts as a powerful reducing agent to aid in biological sulfate reduction processes, ZVI research dates back to mid- to late 1990s.

Administrative Feasibility

Andrews judges some technologies to be infeasible based on perceived administrative implementability problems. For example, Andrews (2004, p. 5) states, "the pipeline and injection options would have required extensive study and permitting. Injection of this

magnitude may not be allowable under federal guidelines." Also, "implementation would likely have required years." Administrative implementability is only one of many factors to be considered in engineering feasibility studies. The time required to obtain permits is generally not considered a fatal flaw in an alternative's implementability, given a good-faith effort to remedy the TDS compliance issues. For example, while Cominco expended 4 years preparing slightly different versions of the technology screening reports, considerable progress toward solving the perceived administrative obstacles could have been made.

Regarding his statements on the administrative feasibility of deep-well injection, Andrews assumes that all 10,000 gpm of the mine's effluent would require disposal. However, the administrative implementability challenges as well as the technical challenges to injection might be overcome by designing a comprehensive alternative in which injection is only one component, for example, for disposing of the reject from a nano-filtration system.

The hypothetical time scale presented by Andrews (2004, p. 5 through 7) as an example of the process and schedule required to gain regulatory approval of a new treatment technology is exaggerated. As only one of many possible examples, Andrews states that a total of 25 months would be needed to perform bench-scale testing, report the results, and select an alternative based on the testing results. This time estimate is excessive. Given a good faith effort, bench testing could be accomplished in less than one fourth to one third as much time. Other time requirements stated by Andrews are similarly exaggerated.

It should be noted that, according to the documents, the mine water treatment process was altered between 1997 and 1999 by the addition of a sulfide precipitation unit. Despite the administrative obstacles cited by Andrews for implementing TDS technologies, the treatment process was modified by adding a sulfide precipitation unit within a two-year time period, i.e. between the last two versions of the technology screening reports.

Qualifications

Mr. Fischer's qualifications as an environmental engineer are summarized in this section. Detailed information about his qualifications are presented in the attached *Curriculum Vitae.*

1. Education

M.S., 1989, Civil/Environmental Engineering, Colorado State University;
B.S., 1976, Natural Resources Management and Biological Sciences, Colorado State University

2. Professional Registration

Professional Engineer, Colorado Reg. No. 31660;
Wyoming Reg. No. 8553

3. Experience

Randolph C. Fischer is a private consulting environmental engineer providing design and

process engineering expertise for remediation of sites contaminated with acid mine drainage, organic compounds, cyanide, and heavy metals. Mr. Fischer performs technology evaluations, treatability testing, and design of passive and active systems for treatment of acid mine drainage, mine waters, and mining wastes. He is a process designer of industrial and municipal wastewater treatment systems with experience in designing and performing bench- and pilot-scale wastewater treatability studies. Mr. Fischer is also experienced in managing and conducting field pilot testing and designing, installing, and operating soil vapor extraction, air sparging, and two-phase vacuum extraction systems at solvent and hydrocarbon contaminated sites. International project experience includes projects in Canada, Australia, Brazil, Japan, Mexico, Argentina, Venezuela, Ecuador, Peru, and the Sultanate of Oman.

4. **Representative Projects**

Projects representing Mr. Fischer's professional experience are summarized, as follows:

- **Inter-American Development Bank (IDB) 2002 to 2003** - Environmental engineering consultant on an acid mine drainage project in southern Brazil as a subconsultant to Environment and Energy Solutions, Inc. of Tokyo, Japan.

- **Japanese International Cooperation Agency (JICA) – 2000 to 2001** - Served as remediation engineer for a multi-disciplinary team of scientists and engineers working with the Omani Ministry of Commerce and Industry to mitigate groundwater pollution from a copper mining and smelting facility in the Sohar Mining District in the Sultanate of Oman.

- **Japanese International Cooperation Agency (JICA) 1997 through 1998** – Worked with the Brazilian government to reclaim areas in the state of Santa Catarina, Brazil, affected by coal mining activity, with emphasis on mitigating the effects of acid rock drainage (ARD).

- **Summitville Mine Superfund Site, 1995 - 1996** - Managed treatability studies and designed bioremediation systems for cyanide-contaminated wastes and leachate solutions at the abandoned mining site in southwestern Colorado.

- **Jasper County, Missouri, Superfund Site**, 1994 - Managed field and laboratory treatability studies of passive mine drainage treatment opportunities at the Jasper County portion of the Tri-State lead/zinc mining district.

- **Sydney, New South Wales, Australia**, 1996 - Designed a groundwater remediation systems for a former chemical plant site.

- **Wyoming Department of Environmental Quality (WDEQ) 1995 - 1999** - Managed remediation of five leaking underground storage tank (LUST) sites in Laramie, Wyoming.

- **Mining-related CERCLA Feasibilty Studies** – Mr. Fischer has completed or is currently

working on the following feasibility studies at mining-related superfund sites:

- Bunker Hill, Idaho, Superfund Site (gold/silver mine site) - 1991;
- OU-3/OU-4, Cherokee County, Kansas, Superfund Site (lead/zinc mine site) - 1995;
- OU-6, Cherokee County, Kansas, Superfund Site (lead/zinc mine site) - 2003;
- OU-1/OU-4 of the Jasper County, Missouri, Superfund Site (lead/zinc mine site) – 1994 - 2002;
- OU-1 of the Tar Creek, Oklahoma, Superfund Site (lead/zinc mine site) – current.

- **Mine Environment Neutral Drainage (MEND) Program**, 1998 – 1999 - Prepared sections on passive treatment of acid mine drainage for the Acid Rock Drainage Treatment Technology Handbook. This handbook is a comprehensive manual on the chemistry, causes, environmental impacts, and control of acid mine drainage. The treatment handbook is available from Natural Resources Canada.

- **Eagle Mine Superfund Site, Gilman, Colorado, 1990 - 1992 and 1998**. Performed laboratory- and field-scale treatability tests leading to the design of a 500 gpm mine-water treatment plant. Also conducted treatability tests to evaluate the feasibility of implementing passive mine water treatment at the site.

Compensation

Randolph Fischer is a private environmental engineering consultant and is being compensated at the rate of $85 per hour for preparation of this rebuttal report.

Other Cases

Mr. Fischer has not worked on other cases as an expert witness in the past 4 years.

Expert Report of Dr. Michael Kavanaugh

In

Enoch Adams et al.
v.
Teck Cominco Alaska Incorporated

Prepared For
Luke Cole
Attorney for the Plaintiffs

Prepared by:

Michael Kavanaugh
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160 Wood Street
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December 24, 2004

I declare under penalty of perjury that the contents of this report is true and correct to the best of my knowledge.

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DEPOSITION EXHIBIT
PENGAD-Bayonne, N.J.
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Kavanaugh

Expert Report of Dr. Michael Kavanaugh

1. Summary

This report is based on information available to me as of December 24, 2004. If more information and data become available, particularly data about the type and costs of treatment options needed to comply with the Total Dissolved Solid (TDS) permit limits, then I may amend this report. This report focuses on the economic benefit gained by Teck Cominco by exceeding its TDS limits at its Red Dog mine. I focus on TDS limits because they are the bulk of the violations alleged in the revised complaint.[1] At this time no one knows the specific pollution control projects that were needed to bring the Red Dog mine into compliance with its Clean Water Act discharge permits between June 1, 1999 and August 28, 2003. Plaintiffs' engineering experts suggest a process consisting of feasibility and investigative studies followed by implementation of a suite of compliance projects.

Teck Cominco Alaska Incorporated is the operator of the Red Dog mine. Its ultimate parent is Teck Cominco, a mining company that explores, develops and produces metal and minerals worldwide. Teck Cominco, in my opinion, gained an economic benefit of at least $27.2 to $30.8 million because it failed to comply with the TDS limits in its discharge permit when it discharged water from Red Dog to waters of the United States. The range results from alternative measures of the opportunity costs of the funds needed for pollution control. This range underestimates Teck Cominco's economic benefit because the benefit estimate is focussed only on TDS and there are other exceedences and because the cost of controlling TDS that is used as basis for the benefit estimate is cautiously understated.

Teck Cominco produces the discharged water at its Red Dog mine site and at its port site during mining operations that generate positive cash flows.[2] Specifically, at the mine site water is discharged into waters of the United States that is polluted during processing of ore into concentrates and from runoff from slag heaps; at the port site discharges result from operation of a sewerage treatment plant and from drainage from concentrate storage.[3] The discharged water is required to meet the limits of a

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[1] Revised Complaint for Declaratory and Injunctive relief and Civil Penalties

[2] Teck Cominco is the largest zinc mine in the world and is likely to remain so for the foreseeable future. Letter to shareholders and employees from David Thompson, President and Chief Executive Officer, Cominco Annual Report 1999, Feb 29, 2000. Cash-flow data from Teck Cominco Alaska Incorporated financial statements at TC 027808 RD, TC 027734 RD and TC 027695 RD.

[3] Revised Complaint for Declaratory and Injunctive relief and Civil Penalties, ¶18, ¶40.

EXHIBIT 1

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discharge permit. Typically, meeting discharge limits requires spending funds to construct and operate pollution control equipment. Funds not spent for pollution control are available to Teck Cominco for other remunerative projects. The value of the funds made available is measured at their equity cost and at a weighted-average of their equity cost and their debt cost.

The limits of Teck Cominco's discharge permits for Red Dog were modified as of August 28, 2003. The pollution control projects needed to meet the limits after August 28, 2003 are not the same as those that were needed between June 1, 1999 and August 28, 2003. As a result, Teck Cominco avoided entirely the spending for studies, investigations, and projects that were needed for compliance with the unmodified permit, had the use of the funds not spent for pollution control, and gained an economic benefit from its noncompliance.

Economic benefit is a statutory penalty factor under the Clean Water Act. It is the cash that if removed from the defendants today will leave them in the same financial position had they complied in the past. Teck Cominco – unless it observed the limits of its mine site and port site discharge permits -- was not permitted to discharge to the waters of the United States. Teck Cominco , however, did not comply with the limits in its permits and discharged to water of the United States.[4] In so doing it avoided the spending needed for determining, building and using the pollution controls that would make the discharges meet the limits in its permit. For avoided costs economic benefit is measured as the after-tax, present value of the cash flows needed to conduct the studies and investigations, and purchase and operate the controls needed for compliance with the permit.[5] Although unlikely, if pollution controls are unavailable then Teck Cominco – to conform its discharges to the terms of its permits -- would have to reduce or cease production. In this instance, the benefit is measured as the after-tax present value of the cash flows from the operations that produced the extra production.

The analysis in this report is based on:

- Cost estimates from plaintiffs' engineer experts and screening studies performed for the Red Dog mine (Section 3.1.1);
- Compliance and noncompliance dates (Section 3.3);
- Rates of price change (Section 3.4);

[4] Revised Complaint for Declaratory and Injunctive relief and Civil Penalties, ¶3.
[5] For delayed costs the benefit is measured as the after-tax, present value difference between the cash flows needed to comply on-time and the cash flows used to comply late.

- The statutory limit of U.S. and Alaska corporate income tax rates (Section 3.5);
- The opportunity cost of capital (Section 3.6); and,
- Payment of a penalty by the last day of 2004; later payment increases the benefit.

Sections 2 and 3, respectively, describe and apply the method and data used in the benefit analysis. Briefly, the method is an after-tax, present value analysis. The data are publicly available, available from the defendants, or available from plaintiffs' engineering experts.

I reviewed and used Teck Cominco financial statements from 1999 to 2003 to conduct a financial analysis to determine the defendant's ability to pay a penalty. I describe this analysis in Section 4. I conclude that there is a 50/50 chance that Teck Cominco can afford a lump sum penalty payment of $65 million.

According to Section 309 (d) of the Clean Water Act, 33 U.S.C. 1319 (d), there are other factors (e.g., seriousness of the violations, deterrence) that a Court may consider when assessing a penalty. This report addresses only economic benefit. Accordingly, for deterrence or to address the seriousness of the violation a penalty in excess of economic benefit is needed. Appendix A contains my resume and a listing of trial and deposition testimony given since January 1990. I am compensated on all work on a time and material basis at the rate of $125.00/hr.

2. Economic Benefit Method

The federal environmental laws and their implementing regulations set minimum standards for protecting human health and the environment. When minimum standards are not met, civil penalties may result. One part of a civil penalty is the economic benefit that a violator gained by failing to meet the standard. Other parts include the seriousness of the violation, the willfulness of the violation, the harm to the environment and any other factor justice may require. Removing the benefit helps level the economic playing field and helps prevent violators from obtaining an unfair financial advantage over competitors who complied. Removing the economic benefit is a first step in providing an incentive to protect the environment and public health and to help deter future violations by the violator and others.

Economic benefit is the cash that if removed from the defendant today will leave it in the same financial position had it acted to make its discharges comply with the terms of its permit. Since removing economic benefit only returns the violator to the same financial position it would have been in had it complied on time, additional penalty

amounts may be needed to address the other penalty factors. These other factors may include the seriousness of the violations, the harm to the environment and deterrence of future violations by the defendant and other members of the regulated community.

Economic benefit focuses on the violators' economic gain from noncompliance. The gain may occur because the violator gained a revenue advantage by acting illegally or because it gained a cost advantage by delaying or avoiding necessary pollution control expenditures. The gain arises because funds not spent on environmental compliance are available for other, remunerative projects. The gain arises regardless whether the defendant acted deliberately to delay or avoid compliance, or even if the defendant had been unaware of its noncompliance.

For avoided costs economic benefit is measured as the after-tax, present value of the cash flows needed to determine, build and operate the controls needed for compliance with the permit. For delayed costs the benefit is measured as the after-tax, present value difference between the cash flows needed to comply on-time and the cash flows used to comply late[6,7]. Although unlikely, if pollution controls are unavailable then– to conform its discharges to the terms of its permits – a discharger would have to reduce or cease production. In this instance, the benefit is measured as the after-tax, present value of the cash flows from the operations that produced the extra production.

"After-tax" means allowing for the deductions available for business spending. "Present value" means placing cash flows on a common temporal basis so that a comparison may be made. An economic principle is that cash-flow value depends on when it occurs. A cash flow today is worth more than a cash flow tomorrow because today' s flow can be invested and earn additional revenue. A future flow is adjusted to present value by estimating the return earned on a present cash flow so that the

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[6] Delayed pollution control spending may be of two types: recurring and one-time. For one-time costs, I calculate the benefit as follows. First, I compute the after-tax present value ATPV of purchasing the item ontime. Second, I compute the ATPV of purchasing the item later. Third, I find the difference between the first and the second sums. The difference is the benefit

[7] For recurring costs, I would compute the benefit in three steps. First, I would calculate the after-tax cash outlays associated with installing the pollution control system on-time and operating it into the future using a replacement cycle for the system equal to its useful life. I would express the outlays as a single figure in today' s dollars. Second, I would calculate the after-tax cash outlays associated with installing the same system later and operating it into the future using a replacement cycle for the system equal to its useful life. I would express the outlays as a single figure in today' s dollars. The same time horizons are used for both the stream of cash outlays that begin on-time and the stream of cash outlays that begin later. Third, I would subtract the second set of outlays from the first set of outlays. This difference is the economic benefit.

present flow, plus its return, equals the future flow. Opportunity cost quantifies this economic principle. It is a scale that states by how much a present dollar exceeds a future dollar. This depends on the company' s earning opportunities from its business resources. I estimate the earning opportunities available from business resources by using the capital asset pricing model.

This approach is consistent with the approach of the U.S. Environmental Protection Agency (EPA) for estimating the economic benefit of non-compliance.[8] I use this approach in other environmental enforcement cases and Courts have accepted it (e.g., PIRG v. PD Oil Terminals; SCLDF v. CC of Honolulu, 90-00219 ACK; Friends of the Earth v. Laidlaw Environmental Services (TOC) Inc., DSC 3-92-1697-17).

3. Application of Economic Benefit Method

This calculation of economic benefit is based on Teck Cominco's exceedences of its permit limits for TDS at its Red Dog mine. The reasons for this focus are:

- The Revised Complaint alleges 2309 violations at the mine site and most (1230) are for TDS; and,
- Controlling TDS is more costly than monitoring and reporting so a TDS violation provides more benefit than a reporting violation.

Teck Cominco gained an economic benefit because it avoided:

- The costs of studies and investigations to determine the projects needed for compliance with the TDS limits in its discharge permits; and,
- The capital and operating and maintenance (O&M) cost for TDS control projects from June 1999 to August 2003.

The benefit is calculated using an equity cost of capital and, alternatively, a weighted-average cost of capital. The approach I followed may be summarized as follows. First, plaintiffs' engineering experts provided cost estimates of the studies and investigations needed to determine the pollution control projects needed for permit compliance. Second, I reviewed screening studies produced for Teck Cominco of possible pollution control projects at the Red Dog mine site. I selected a highly ranked, low cost pollution control project to serve as a token project. Next, I applied an annual rate of price change to achieve comparability. Then, I found the after-tax value by depreciating or expensing the item and applying statutory maximum federal and state tax rates. Finally, I found the present value as of Dec 31, 2004. The benefit for avoided items is the sum of the after-tax present value of the avoided expenditures. The results are based on:

[8] The approach is detailed in the *BEN Users Manual.*

- cost estimates from expert engineering opinion and defendants' screening studies;
- dates of compliance, non-compliance, and expected settlement or penalty payment;
- rates of price change;
- the statutory limits of U.S. and Alaska corporate income tax rates; and,
- the opportunity cost of capital.

3.1 Cost data for preventing discharges

Plaintiffs' engineering experts inform me that in order for Teck Cominco to comply with the terms of its unmodified permits for TDS at Red Dog it should have performed feasibility and investigative studies to determine the projects that were needed for compliance. In the opinion of the engineering experts the studies and investigations would have identified a suite of projects that could have brought about compliance. Most likely the suite of projects would have included water management, add-on controls to existing treatment processes, possibly application of a membrane technology and provisions for injection of fluid by-products of pollution control processes. The cost (in 2004$) of the feasibility studies is estimated by the engineering experts at $1 million and the cost of the investigations is estimated by the engineering experts at $5 million. Since the studies and investigations were never performed their cost is avoided.

Teck Cominco commissioned screening studies that discussed various control options for Red Dog and estimated capital and operating costs.[9] I use the 1999 study to give a sense of the magnitude of the lower bound of costs Teck Cominco avoided in failing to implement the projects it needed to comply with its discharge permits for TDS control at Red Dog.[10] I am not opining that any particular project would achieve compliance. I am proposing only that at the least spending on the order associated with these projects was needed. In particular, Table 6 of the 1999 report ranks projects for TDS management based on annual operating and maintenance costs plus amortized capital cost. The two highest ranked projects (i.e., the low cost projects) have capital costs (in 1999$) ranging from $13.8 million to $15.3 million and annual O&M cost (in 1999$) ranging from $750,000 to $2.5 million. I estimate

[9] *Effluent Treatment and Water Management for TDS Control, Teck Cominco Mine*, Andrews et al., December 1996; *Effluent Water Management Options for Additional Control of Key Metals, Teck Cominco Mine*, Andrews et al, August 1997, and *Update, Effluent Treatment and Water Management for TDS Control, Teck Cominco Mine*, Andrews et al., March 1999
[10] *1999 Update, Effluent Treatment and Water Management for TDS Control, Red Dog Mine*, Andrews et al., March 1999.

the economic benefit from avoiding the costs associated with the highest rank project (i.e., the low cost project). The costs associated with the highest ranked project have capital outlays of $15 million and annual O&M of $750,000.

3.2 Dates

The dates that underlying the benefit estimate are:
Feasibility study – June 1, 1999
Investigations - June 1, 1999
Projects (capital) - June 1, 1999
Projects (O&M) - June 1, 1999 to August 28, 2003

The feasibility study and the investigation are activities that had to occur prior to constructing the projects. To be cautious, however, I estimate the benefit for avoiding the studies and investigation on the same date as the project would have had to begin operating, June 1, 1999. Obviously this practice understates the benefit received by Teck Cominco.

3.3 Measures of price change

The plaintiffs' engineers cost estimates are stated in 2004 dollars while the cost of the screening options in the defendants' report are circa 1999. To achieve comparability I apply average annual rate of price change to this data. I use the average price change in the economy over the period 1999-2002 of 1.8%.[11]

3.4 Taxes

I adjust for tax effects using the combined statutory limits of U.S. and Alaska corporate income tax rates of 41.1%.[12] I depreciate capital costs using the minimum length of time permitted by U.S. tax code.

3.5 Opportunity cost

I measure opportunity cost in two ways. First, I measure the equity cost of capital by applying the capital asset pricing model to a project of average risk. The model estimates the expected return to equity by adding a risk-free rate to a risk premium. The risk-free rate is the return on U.S. Treasury bills and the premium is the amount

[11] This rate is reported in the Economic Report of the President 2003, statistical section.
[12] The Tax foundation reports a statutory maximum rate for Alaska at 9.4 and IRS publication # 542 reports the corporate tax rate at 35%. The combined rate is 41.1%. This rate is the "custom" rate for Alaska in EPA's current BEN Model.

by which stock market returns exceed returns on Treasury bills. Ibbotson Associates reports this information in *Stocks, Bonds, Bills and Inflation: yearbook*. The equity cost of capital is 13.4%. Second, I calculate the weighted average cost of capital. This approach blends the equity cost of capital with borrowing cost. I use Teck Cominco's borrowing from 1999-2003, a capital structure of 25% debt and 75% equity and an equity return. This produces an estimate of 11.1%. For projects that do not produce a positive cash flow and therefore cannot generate the cash flows to repay principle and interest on debt I favor using the equity return as the better measure of opportunity cost.

3.6 Results

Teck Cominco-- because it did not observe the limits of its discharge permit-- was not permitted to discharge to the waters of the United States. Teck Cominco, however, discharged to water of the United States and avoided the spending needed to observe the limits in its discharge permit. The benefit from avoiding the studies, investigation and installation and operation of the needed equipment ranges from $27.2 to $30.8 million. These are cautious estimates that understate Teck Cominco's benefit. The principle reason for this opinion is that the cost of the suite of projects needed for compliance is likely to be much larger than the $15 million capital /$750,000 O&M expense that underlie the estimates in the following table.

Teck Cominco: Benefit estimate by item by measure of opportunity cost

Item	Equity cost of capital	Weighted average cost of capital
Feasibility studies	1.1	1.0
Investigations	5.4	4.8
Pollution control project(s)	24.3	21.4
Total (Millions, January 2005 $)	30.8	27.2

4. Ability to Pay

I reviewed the financial performance of Teck Cominco Alaska from 1999 to 2003 and used the information in its financial statements to perform a cash-flow analysis that is consistent with EPA's ABEL model.[13]

[13] The Approach is detailed in the *ABEL User's Manual*

4.1 Cash-flow analysis

Typically, a violator who wants to remain in business complies with environmental law and regulation by obtaining a permit, making investments in pollution control equipment needed to comply with the permit, operating and maintaining the equipment, and paying a civil penalty if it violates that permit. I refer to all of these collectively as "environmental spending". Environmental spending like any other type of spending must be paid out of cash flows. Accordingly, the measure I use for an ability to pay analysis is to determine the availability of cash flows over the near term. I assume alternatively that all of the available cash flows are available for environmental spending and that only 75% of the available cash flows could be used for environmental spending.

My method, which is consistent with EPA's method used in its ABEL model, is to:

- calculate the defendant's cash flows over the past five years in constant 2003 dollars;
- forecast the amount of cash flow available under varying probability levels; and
- apply reinvestment rates to find the amount available for environmental spending.

4.1.1 Past available cash flows

Available cash flows are the cash receipts minus the cash disbursements from a group of assets for a given period. In this instance I use the annual net income from Red Dog's operations adjusted for depreciation, a non-cash cost. The available cash flows for are shown below and are based on Tech Cominco Alaska Inc.'s financial statements.

Table: Teck Comenco Alaska available cash flows by year (thousands)

Cash flows	2003	2002	2001	2000	1999
income	-23,479	-36,693	-25,345	75,187	114,421
depreciation	32,676	32,366	27,932	28,051	28,985
total	9,197	-4,327	2,587	103,238	143,406
constant 2003$	9,197	-4,405	2,681	108,914	154,013

Source: Annual Reports

Adjusted to constant 2003$ using GDP price index rate of 1.8% per year

4.1.2 Future available cash flows

Future available cash flows are influenced by the variability of past cash flows, the reinvestment rate and a present value factor.

Variability. First, I compute the average and standard deviation of available cash flows for 1999 to 2003. The average available cash flow is $65 million with a standard deviation of $78.6 million. I used the Student–t distribution to determine the probability that next year's available cash flow would exceed a given amount. The table below shows available cash flows for selected percentages. Row 1 indicates that there is a 10% probability that next year's available cash flows will exceed $186 million for a 0% reinvestment rate; and, row 9 indicates there is a 70% probability that next year's available cash flows will exceed $16 million for a 25% reinvestment rate.

Table: Available cash flows by probability and reinvestment rate
(Millions of 2003$)

Probability	0% Reinvestment	25% Reinvestment
10%	$186	$140
20%	139	104
30%	110	83
40%	87	65
50%	65	49
60%	44	33
70%	21	16
80%	(9)	(7)
90%	(55)	(41)

Reinvestment. Reinvestment is that portion of the cash flow that is reinvested in plant and equipment rather than for environmental spending. The USEPA standard assumption for reinvestment is that is all available cash flows are available for environmental spending, a 0% reinvestment rate. Row 7, for example, shows that with a reinvestment rate of 0% there is a 70% chance that next year's cash flows available for environmental spending will exceed $21 million. Row 7 also shows with a 25% reinvestment rate there is a 70% chance that next year's cash flows available for environmental spending will be $16 million.

Present value. Finally, standard EPA practices is to project five years into the future and calculate the present value of the future flows. I departed from this practice and projected only one year. The effect of this assumption is to give a conservative bias to the estimate of Teck Cominco's ability to pay for environmental spending.

4.2 Ability to pay conclusion

An aggressive argument is that if there was a 10% chance that Teck Cominco would have available cash flows then it has the ability to pay for environmental spending. For that case Teck Cominco would have the ability to spend $186 million. A less aggressive stance is that if Teck Cominco had a 50/50 chance of having available cash flows, then that sum would indicate ability to pay. For that case, Teck Cominco has the ability to pay $65 million for environmental spending.

Sources Considered

Statistical Abstract of the United States, U.S. Bureau of the Census, Department of Commerce, GPO, 1995.

Economic Report of the President, Council of Economic Advisors, U.S. GPO, January 2003.

Stocks, Bonds, Bills and Inflation, Ibbotson Associates, 2003.

BEN Users Manual, USEPA, 1993, 1997, 1999.

Publicly available financial records of Cominco Ltd. and Teck Cominco.

Teck Cominco Alaska Incorporated, Consolidated Financial Statements, 1996-2003

Effluent Treatment and Water Management for TDS Control, Red Dog Mine, Andrews et al., December 1996;

Effluent Water Management Options for Additional Control of Key Metals, Red Dog Mine, Andrews et al, August 1997,

Update, Effluent Treatment and Water Management for TDS Control, Red Dog Mine, Andrews et al., March 1999

Revised Complaint for Declaratory and Injunctive Relief and Civil Penalties

ABEL User's Manual, USEPA

IRS publication # 542

Formulas used

Avoided spending –capital construction

Cost = quote / (1 + price change)^(quote date - on-time date)

After tax = cost – present value of depreciation

Present value of depreciation = cost * depreciation rate * tax rate * present value factor

Benefit = after tax * (1 + opportunity cost)^(trial date - on-time date)

Avoided spending –O&M, studies, investigations

Cost = quote / (1 + price change)^(quote date - on-time date)

After tax = cost * (1 - tax rate)

Benefit = after tax * (1 + opportunity cost)^(trial date - on-time date)

Appendix A

MICHAEL KAVANAUGH
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PRESENT POSITION: Private practice, since 1985

PREVIOUS POSITIONS
Senior Economist/Project Manager, ICF Incorporated, 1983-85, Washington DC
Research Director, Public Interest Economics Foundation, 1976-83 Washington DC & San Francisco CA
Assistant Professor, Northern Kentucky University, 1975-76

EDUCATION
Ph.D., Economics, University of Cincinnati, 1975
BA, Economics, Xavier University, 1970

EXPERIENCE
Dr. Kavanaugh is:

- an independent research economist with over twenty-five years of experience;
- a national expert in environmental enforcement and policies for municipal and industrial pollution sources;
- experienced in natural resource damage assessment and regional economic impact assessment; and,
- an author of groundwater management and climate change papers.

Short descriptions of selected projects follow.

ECONOMICS & FINANCE
Applied economics to many of the environmental changes of the last twenty-five years including:

- estimating the benefits of cleaner beaches and rivers;
- developing methods to determine the effects of water quality policies on agricultural output, employment, and income;
- developing methods to estimate the benefits of preserving groundwater quality;
- estimating expected and realized benefits and costs of irrigation projects; and
- critiquing efforts to regulate effluents from several industries.

Examples include:

Exxon Valdez - Estimated the employment and income effects from spending the civil settlement. The work involved characterizing the options in the restoration plan in terms of input/output models.

Ohio River - valued public resource damages from spills from tugs and barges. The work combined results from the Natural Resources Damage Assessment models for Great Lake environments, studies of the costs of reducing risks to drinking water, and restoration costs.

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Kailua Beach State Park - valued a three-mile public beach based on recreational use and estimated the damage to the beach from wastewater treatment plant effluent. The work involved reviewing, updating and synthesizing a variety of studies that valued recreation.

Florida Beaches - valued beach closures from pollution at several beaches. The work involved extensive use of the Natural Resource Damage Assessment models for coastal and marine environments.

Provided expert economic and litigation support services to the ~~United States (and others) in Clean Water Act, Clean Air Act,~~ Superfund, Resource Conservation and Recovery Act Enforcement Cases.

Designed and used financial after-tax, cash-flow models to:
- estimate the benefit gained by entities that violate their discharge permits;
- measure the effect of penalties on their financial position; and,
- estimate the residential burden for controlling overflows from combined and separated sewers.

Advised environmental groups on the use of contingent valuation to value natural resource damages and commented on the Federal Register Notice on the use of contingent valuation to determine damages.

Testified about the influence of groundwater quality on residential property values.

Design team member to size and fund the CERCLA Superfund and the WVA acid mine drainage reclamation fund.

Testified about the change in rates needed to pay for adopting cooling water intake controls at a nuclear power plant.

Testified to the benefits North Miami received from a landfill and on the economics of operating a landfill (Orange County, NY).

Conducted several analyses of the U.S. petroleum industry: to estimate current and future production in wetlands and in the arctic; and, to estimate the cost effectiveness of technologies to control produced water discharges.

Estimated current and future greenhouse gas emissions by fuel, sector, and region. The work involved estimating long-term energy use using an economic model based on prices and income and forecasting combustion technology. Atmospheric modelers use the work.

Advised and submitted affidavits supporting Alaska's position on oil and gas leasing in the North Aleutian Basin.

PUBLICATIONS

"Fuel economies available from ultrahigh bypass jet engines" in *Cost estimates of measures available to reduce U.S. greenhouse gas emissions by 2010*. ICF Washington D.C. 1990.

"End-use efficiency and NOx emissions in aviation". In S. Meyers, Ed. *Energy efficiency and structural change: Implications for the Greenhouse problem.* Lawrence Berkeley Laboratory, Berkeley CA 1988.

Estimates of future CO, N2O and NOx emissions from energy combustion, *Atmospheric Environment*, March 1987.

Tropospheric CH4/CO/NOx: The next 50 years. Co-author with Anne M. Thompson. UNEP/USEPA International Ozone Conference, 1986.

Eliminating CFCs from aerosol uses: the U.S. experience and its applicability to other nations. U.S. Environmental Protection Agency, Washington, February 1986.

The 1983 world oil surplus: some implications for OCS leasing. Prepared for the U.S. House Subcommittee on the Panama Canal/OCS Washington, April 1983.

The effect of OCS leasing schedules and procedures on fair market value. Paper presented to the Western Economic Association, Seattle July 1983.

Efficient strategies for preserving groundwater quality, with Rob Wolcott. U.S. Environmental Protection Agency, May 1982.

Exclusive territorial distributorships and consumer welfare: the case of beer. Food Marketing Institute, Washington D.C. 1982.

The Great Giveaway, with others, Sierra Club, October 1982.

The public benefits of the proposed Union Pacific, Missouri Pacific, Western Pacific Consolidation. Interstate Commerce Commission, August 1981

Regional economic impacts of OCS oil and gas development. with Susan Little and Rob Wolcott. Governor's Office of Planning and Research, California, November 1976.

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MICHAEL KAVANAUGH

Federal Court Trial Testimony Since 1/91

NRDC v. Texaco - Wilmington - 2/91, 88-263-JRR
U.S. v. City of San Diego - San Diego - 2/91, 88-1101-B(IEG)
SCLDF v. City/County of Honolulu - Honolulu - 1/93, 90-00218-HMF
Friends of Earth v Laidlaw - Columbia SC - 11/93, DSC 3-92-1697-17
PIRG v. MEI - Newark - 1/94, DNJ 89-3193
Friends of Earth v Laidlaw - Columbia SC - 7/95, DSC 3-92-1697-17
Friends of Earth v. Gaston Recycling 7/95, DSC 3-92-2574-0
PIRG v. Hercules - Camden NJ - 2/97, DNJ 89-2291
~~U.S. v. Rapanos et al. - Detroit MI - 10/2000, 94-CV-70788DT~~
PIRG v. Rahway - Rahway NJ - 4/2001, UNN-L-163-98

Deposition Testimony since 1/91

U.S. v. San Diego 1/91, 2/91, 88-1101-B(IEG)
SCLDF v. C&C Honolulu (Sand Island) 2/91, 90-00219 ACK
U.S. v. Louisiana Pacific & Simpson Paper 4/91, C-87-0567-MHP
PIRG v. Hercules 7/91, DNJ 89-2291
U.S. v. Corning 9/91, 3:CV-90-207

NRDC v. Total Petroleum 5/92
PIRG v. Witco Chem. 5/92, DNJ 89-3146
Hawaii's Thousand Friends v. C&C Honolulu (Honouliuli) 6/92, 90-00218-HMF
PIRG v. Circuit Foil 12/92, DNJ 89-5371

Arkansas Wildlife Fed. v. Hudson Food 5/93
U.S. v. Lawrence Cty. 5/93, C-1-91-302
PIRG v. Essex Cty. 6/93, DNJ 92-4465

TN. Enviro. Council v. Dana 4/94, 1-92-0074
Friends of the Earth v. Gaston Recycling 1/95, DSC 3-92-2574-0
Stevens v. McGinnis, Inc., et al. 2/95, C-1-93-442
Save Our Beaches v. C&C Honolulu (Kaneohe/Kailua) 3/95, 92-00263 DAE
City of Independence, Mo. v. Amoco 8/96
California Sportfishing Alliance v. El Dorado 8/96, CV-S-95-699
SF Baykeeper v. Dow Chemical Co., 9/98, C97-01988
American Canoe Association v. Green Valley-Greenwood PSD, City of St. Albans and Dunbar PSD, WVA. 10/98, 97-0949
Interfaith Community Organization v. Shinn *et al*, 2/00, 93-4774, 94-3434, 94-3793
U.S. v. Rapanos *et al*, 9/00, 94-CV-70788DT
American Littoral Society V. Rahway Valley Sewerage Authority 10/00, UNN-L-163-98
American Canoe Association v. WASA, 4/02, 1:99cv02798(HHK)
Sierra Club *et al* v. Hamilton County, 4/03 1-02-107

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Appendix B

Avoided spending

item	token project				
quote	15,000,000				
	6/1/99				
	cost	value of depreciation	after-tax cost	present value	
ontime	15,000,000	4,459,578	10,540,422	21,285,928	
	6/1/99				

opportunity cost	13.4%
payment date	12/31/04
price change	1.8%

value of depreciation

		depreciation rate	tax rate	depreciation	value
1999	1	0.145	0.411	893,925	839449
2000	2	0.245	0.411	1,510,425	1250776
2001	3	0.175	0.411	1,078,875	787841
2002	4	0.125	0.411	770,625	496246
2003	5	0.310	0.411	1,911,150	1085266
2004	6	0	0.411	-	0
2005	7	0	0.411	-	0
2006	8	0	0.411	-	0
					4,459,578

O&M

	6/1/99			
Jun-99	437,500	$437,500	$257,688	$520,389
Jul-00	750,000	$764,658	$450,383	$793,534
Jul-01	750,000	$778,422	$458,490	$712,361
Jul-02	750,000	$792,433	$466,743	$639,492
Jul-03	500,000	$537,798	$316,763	$382,718
				$3,048,494

Total Benefit

Capital	$21,285,928
O&M	$3,048,494
	$24,334,421

study	12/15/04	Jun-99		
	1,000,000	$905,810	$533,522	$1,077,425
investigation	12/15/04	Jun-99		
	5,000,000	$4,529,049	$2,667,610	$5,387,123

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CERTIFICATE OF SERVICE

I certify that on the 23rd day of December 2004, a true and correct copy of the EXPERT REPORT OF MICHAEL KAVANAUGH was served via first class mail, postage prepaid, on the following counsel of record:

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